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Strategic Implementation of Navy and Marine Corps Unmanned Combat Air Vehicles with Respect to Military Transformation

Prepared By

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10 May 2002

Signed: [signature]

Abstract

Unmanned combat air vehicles (UCAVs) have taken on a greater strategic role in the U.S. Armed Forces, as evidenced by recent operations of the Predator unmanned aerial vehicle firing Hellfire missiles against Taliban and Al Qaeda forces in Afghanistan. Although no naval UCAVs currently exist, U.S. Navy and Marine Corps forces will incorporate and rely upon these vehicles during future combat. For this reason, the Navy and Marine Corps must decide the fundamental strategy and capabilities for these vehicles to avoid using unmanned vehicles where manned aircraft might be more appropriate. Even though UCAVs promise to perform some missions more effectively and less expensively than manned aircraft, they should not be used in combat just because they can, but only if they provide a significant operational or strategic advantage.

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"Now it is clear the military does not have enough unmanned vehicles. We're entering an era in which unmanned vehicles of all kinds will take on greater importance – in space, on land, in the air, and at sea."

President George W. Bush
Citadel speech, 11 December 2001

Overview

The above statement illustrates the strategic shift that is occurring in the United States military through initiatives such as unmanned aerial vehicles (UAVs). In particular, unmanned combat air vehicles (UCAVs) have taken on a greater tactical role, as evidenced by recent operations of the Predator UAV firing Hellfire missiles against Taliban and Al Qaeda forces in Afghanistan.[1] Albeit no naval UCAVs currently exist, the strategic shift implies future U.S. Navy and Marine Corps forces will incorporate and rely upon these vehicles during combat. For this reason, the Navy and Marines must determine the fundamental strategy and capabilities for these vehicles to avoid using unmanned vehicles where manned aircraft or other weapon systems might be more appropriate.

To support the future use of unmanned vehicles, Congress passed legislation mandating one-third of the military's deep strike capability be unmanned by 2010.[2] Even though Department of Defense officials say they cannot meet the deadline, significant funds have been earmarked to honor the legislation's intent. Funding for all military UAV programs in the 2003 budget is over $1.1 billion dollars, and the Navy requested $50 million in 2003 for its own UCAV program, which is an $8 million increase from 2002's budget.[3]

Several factors have contributed to the anticipated boom in naval UCAVs. The Predator reconnaissance UAV was successfully modified with a Hellfire air-to-ground missile system and employed during combat operations in Afghanistan. Also, technology has advanced to the point where it is now feasible to use unmanned vehicles for naval combat operations. Finally, naval UCAVs have a strategic and practical advantage over their land-based counterparts, since the 1988-ratified Intermediate Range Nuclear Forces Treaty prohibits certain land-based cruise missile-like systems; however, the treaty does not restrict ship-based systems.[4]

Current Navy Initiatives

The U.S. Navy has leveraged efforts from Air Force and Defense Advanced Research Projects Agency (DARPA) unmanned programs. Presently, the Navy's stated requirements address a carrier-based UCAV that performs the suppression of enemy air defenses (SEAD), strike, and intelligence, surveillance and reconnaissance (ISR) missions.[5] There is one noticeable difference between the Navy's UCAV mission requirements and the Air Force's requirements: the Navy's includes ISR, while the Air Force's does not. A reason behind the Air Force's omission is they currently utilize other UAVs, such as the ISR proven Predator and Global Hawk, to accomplish this mission.[6]

The Office of Naval Research and DARPA have selected Boeing and Northrop Grumman as the contractors for the UCAV Advanced Technology Program demonstrator. This program will pave the way for a vehicle that could enter operational service by 2015. Navy UCAV guidelines for the demonstrator call for a strike radius of 1000 nm and an ordnance payload of 2000 lbs (to include joint military munitions and the new Small Diameter Bomb).[7] Guidelines also call for the

UCAV to perform a 12-hour ISR mission and operate at a maximum altitude of approximately 35,000 ft. The UCAV is to be the same size class as the F/A-18C aircraft, and based upon analysis by DARPA, the vehicle should have a unit cost one-third that of the Joint Strike Fighter and an operational support cost one-half of an F/A-18C squadron.[8]

Current Marine Corps Initiatives

The Marine Corps has no current UCAV programs underway, but does have several UAV programs presently under development. Their requirements are for a family of inexpensive, man-portable UAVs that meet the commander's battlefield requirements.[9] *Dragon Eye* is one such UAV that weighs 4 lbs, has a 3-ft wingspan and is designed to operate at 35 knots with an endurance of 1 hour. The included 1 lb sensor payload can provide day, low-light, or night infrared sensor imagery to a ground operator. With combat operations ongoing in Kabul, Afghanistan, the Marine Corps is looking to use the *Dragon Eye* to support security forces within the city, and current plans call for fielding over 300 systems.[10]

Transformation: Quantifying the Qualitative

With guidance from Secretary of Defense Rumsfeld concerning the need for today's military to become even more capable in the future, the term *transformation* has become quite prevalent. Transformation is considered to be a revolutionary or significant improvement in hardware, tactics, or doctrine.[11] Proponents of military transformation believe that in times of technological revolution, gradually evolving militaries run the risk of being overtaken by adversaries willing to risk all on revolutionary changes.[12] These visionaries seek a military force that is lighter, more mobile, and more easily deployed to emerging hot spots around the world. While the services get

aboard the transformation bandwagon, *transformation* has been misapplied and even tied to acquisition programs as a way to improve a program's chances of escaping criticism and budget cuts.[13] Understandably, the overuse and misuse of the word has resulted in a partial loss of its intended meaning.

Critics speculate that UCAVs are not transformational but are just the next step in the incremental evolution of aircraft.[14] To prevent pundits from arguing which programs are transformational or not, and to decide if UCAVs have a significant improved capability over manned aircraft, it is desirable to "put a stake in the ground" and quantify this nebulous and overused qualitative word. Borrowing from the engineering and applied sciences disciplines, which routinely perform numerical calculations, the equivalent to *transformation* would be an *order of magnitude* change, which denotes a significant or noteworthy measurable change. Taking the most conservative approach to quantify transformation, an order of magnitude change using the base 2 numbering system will be used to define transformation, thus denoting a measured doubling or halving.[15]

Applying this thesis, unmanned vehicles are considered transformational if they demonstrate at least a twofold improvement in a characteristic (either cost or a capability) when compared to manned aircraft. For instance, if a UCAV performs the same mission, at the same cost, with twice the endurance as its manned counterpart, it *can* be considered transformational. Additionally, if an unmanned aircraft performs the same mission as a manned aircraft, but does it at one-half the cost or less, that *can* be considered transformational. A caveat to this postulate is when one capability is improved while another is lessened. Case in point, if a UCAV has twice

the endurance as a manned strike aircraft, but costs twice as much to purchase and operate, this *cannot* be considered transformational, since flying two sequential sorties of the cheaper manned aircraft would provide the same coverage as the longer endurance UCAV. Therefore, improving an unmanned aircraft's performance at any cost is not in keeping with the transformation ideal.

There is an exception to quantifying transformation, and that is when the unmanned vehicle's novel capability cannot be numerically compared to manned aircraft. For example, the Marine Corps's *Dragon Eye* is man-portable and uses sensors to accomplish its surveillance mission. While manned surveillance aircraft exist with more sophisticated sensors, the portable nature of *Dragon Eye* allows it to provide urban surveillance and operate in a manner manned aircraft cannot. For this reason, it *can* be considered transformational.

Important UCAV Attributes

The Navy, DARPA, and civilian contractors are currently designing naval UCAVs with certain capabilities and performance specifications based on the SEAD, strike, and ISR missions. Regardless of any mission specific design traits, there exist fundamental attributes and capabilities that all naval UCAVs should demonstrate to be operationally viable.

Maintainability and Reliability

At a minimum, future UCAVs need to be as readily maintainable and operationally reliable as contemporary manned aircraft. This ensures the unmanned vehicle can be repaired and perform the missions they were designed to do. A new state-of-the-art unmanned vehicle benefits no one if it is inoperable the majority of the time due to maintenance issues.

Some would argue that survivability should be a required attribute. While highly desirable, the ability for a UCAV to survive battle damage should be considered secondary, especially if the unmanned vehicles have a fractional cost compared to manned aircraft. Designing a UCAV to be highly survivable adds expense and aircraft weight, which reduces aircraft endurance. Also, incorporating inexpensive stealth technology into the design reduces the probability that enemy surface-to-air radar systems will even detect the vehicle; thus, mitigating the need for inherent survivability. Once the technology matures and the price to produce these vehicles is driven down, minimal combat survivability can be considered acceptable due to the vehicle's inherent "throw-away" cost.

Same Air Traffic Control Standards

UCAVs must be able to operate within the same air traffic control standards that are imposed upon manned aircraft. For the Navy, this means carrier-based UCAVs need to operate within the constraints of the normal operational launch and recovery cycle. Furthermore, carrier-based unmanned vehicles must be able to fly day and night landing patterns within the same timing and airspace requirements as their manned counterparts. Imposing different rules upon UCAVs and manned aircraft reduces the carrier's operational effectiveness and efficiency, and whether an aircraft is manned or not should be transparent when operating within the carrier's controlled airspace.

Organic Capability

Naval UCAVs need to remain organic to the battle group, which means they should takeoff and land aboard ships. For example, if a UCAV is to be tactically viable in the strike or SEAD mission, the people that operate and control the unmanned vehicles need to perform the required strike planning alongside aircrew flying the manned strike aircraft. It is necessary for all strike aircraft players to understand the strike timeline, aircraft flight routes, and airspace restrictions.

Some may reason that naval UCAVs and their operators should operate from nearby foreign airfields when the carrier is deployed in-theater. The advantage of land-basing UCAVs would be to remove the requirements for heavier carrier landing gear, thus increasing aircraft endurance. Nevertheless, land-basing UCAVs would reduce their overall combat effectiveness since UCAV mission planners would not work alongside air wing strike planners to develop and understand the mission, contingencies, and last minute changes. For those suggesting that UCAV mission planners should stay aboard the carrier while the unmanned aircraft is based at the nearest foreign field, that option is not operationally viable either. Case in point is the war in Afghanistan, whereby Saudi Arabia stipulated strike aircraft could not operate from its airfields, but support aircraft, such as tankers, could. The Navy cannot afford to have foreign governments dictate the use of naval aircraft during wartime operations.

Significant Cost or Performance Advantage

The U.S. Armed Forces are the premier fighting force in the world, and because of this, implementing naval UCAVs into military strategy runs the potential risk of decreasing U.S. combat effectiveness. Furthermore, substantial research and development costs are associated

with designing future unmanned vehicles, and this money could be used to build additional combat proven manned aircraft. Therefore, future Navy and Marine Corps UCAVs need to provide a significant improved capability or advantage to offset the potential risk and monetary cost, and based on transformation criteria discussed before, this necessitates UCAVs demonstrate a twofold improvement over manned aircraft for it be worth the effort.

Multi-Mission Capability

Current manned naval aircraft routinely perform multiple missions during a single sortie and are retaskable once airborne, and warfare commanders have come to expect this capability from their aircraft. UCAVs of the future should demonstrate this same multi-mission capability to provide decision makers real-time options. Also, considering naval UCAVs are being designed for maximum endurance (some up to 12 hours) and the fact that tactical priorities during combat can change dramatically in a short period of time, unmanned aircraft need to provide mission flexibility in a changing battlefield. For example, marines that are pushing inland might need the reconnaissance capability of the UCAV to detect enemy armored vehicles. Once an enemy vehicle is located, marines would want to target and engage this vehicle with the UCAVs onboard weapons, and after the vehicle is engaged, the UCAVs onboard sensor could be used for bomb hit assessment.

Secure Information Relay

Finally, UCAVs need a secure and reliable means to transmit tactical information to ground stations, shipboard personnel, or directly to other aircraft. Naval UCAVs' transmission and communications systems must be encrypted to prevent enemy interception and exploitation. If a

non-encrypted signal is intercepted by the enemy, he can determine if his mobile assets are being targeted and in turn alert his forces to expedite movement to a safe area.[16]

The ability to relay or "bounce" the UCAVs tactical transmission is a strategic necessity. Since these vehicles are being designed for an over-the-horizon capability, the control station and aircraft would soon reach a relative distance that precludes reception and transmission of information. However, incorporating the ability to use other aircraft, ships, ground stations, or satellites to relay information between the UCAV and control station would greatly increase the vehicle's tactical and effective range.

Getting the Job Done

There are three basic methods of controlling unmanned aerial vehicles. Each method has certain inherent advantages and disadvantages based on its simplicity, cost, and capability. These control methods are remotely piloted, autonomous, and semi-autonomous control. Before discussing these methods, we will baseline the discussion using manned aircraft.

Manned Systems

If using unmanned combat air vehicles is such a great idea, why aren't the skies currently filled with them over Afghanistan? The fact remains performing a combat mission frequently requires reacting to dynamic situations and certain unforeseen circumstances, and manned aircraft have no comparable competition for these situations. Critics of UCAVs have said it is doubtful that computer-brained UCAVs could compete with pilots in situations like air-to-air dogfights where one needs to assimilate information and react immediately.[17] Manned aircraft naturally excel in

performing complex multi-missions with unplanned contingencies since aviators are trained to adapt and react to evolving situations around them. While computers can perform computational and system monitoring functions better than aviators, they have not demonstrated that they can autonomously react to unplanned or unprogrammed contingencies.

Not withstanding, there are inherent disadvantages of manned aircraft compared to their unmanned counterparts. Manned aircraft are in theory more expensive to operate than UCAVs, since one ground operator can monitor and control several UCAVs simultaneously. Additionally, when manned naval aircraft perform missions deep into enemy territory, the aviators run the risk of being shot down and possibly killed or captured. A naval aviator as a prisoner of war poses a political headache and potential operational problem, since U.S. forces would want to avoid targeting enemy positions if a U.S. service member was thought being held nearby. UCAVs could perform these same deep strike missions, but if shot down, the UCAV is just a materiel loss and a pilot's life is potentially saved.[18]

Remotely Piloted Systems

The Predator unmanned vehicle that engaged targets in Afghanistan used a man-in-the-loop control, or specifically was remotely piloted.[19] In this type of system, the aircraft has a communications link with a control station, and the aircraft is given control inputs that dictate the vehicle's flight path and sensor operation. Imagery from the UCAV's sensors is transmitted to the control station, and the manned operator then locates, identifies, and decides when to engage targets. The advantage of this system is that it is relatively unsophisticated since the technology has existed for years to remotely pilot aircraft. The ground station operator is able to decide and

react to the changing situation and direct the next action for the UCAV. More importantly, this system incorporates a man-in-the-loop to maintain accountability and responsibility when releasing live weapons. The rules of engagement for the military services follows a chain of command to determine if the situation warrants armed attack and if collateral damage against non-combatants is an issue. Using a remotely piloted system keeps with this tradition since accountability still resides with human decision makers. The disadvantage of this system is that it is dependent on a constant communications link with the UCAV, and this link may be susceptible to jamming or interference by the enemy. Also, a remotely piloted system requires dedicated personnel to support airborne operations, which may be costly and time consuming during lengthy missions.

Autonomous Systems

On the other end of the spectrum is the autonomous control system. This system uses the unmanned vehicle's onboard computer to locate, identify, track, and expeditiously attack targets, and a control station is only used to receive sensor imagery and aircraft flight information. The foremost advantage of an autonomous system is that it does not require a constant communications link with a control station to perform its mission, and therefore, jamming or interference of the aircraft's communications link by the enemy is not detrimental to the mission. Also, autonomous systems require minimal man-hour support and are consequently less expensive to operate.

The disadvantage of this control system is that it has not been successfully combat proven. Autonomous systems have been used for reconnaissance and surveillance missions, but to date

none have performed in combat. That is due, in part, to the biggest challenge facing autonomous systems used in combat: accountability for making the weapons release decision. Even if the technology advances to allow autonomous combat operations, operational commanders would likely oppose its use. This is because if a bus full of children is misidentified as an armored troop vehicle, and is subsequently destroyed, who would be held accountable for the misidentification and death of the civilians? Would it be the software programmer's fault, the Commanding Officer of the UCAV squadron, or the warfare commander that authorized using the unmanned aircraft? Because of this dilemma, a purely autonomous system should not be used in combat.[20]

Semi-Autonomous Systems

Semi-autonomous systems hold the greatest promise for success. In this control method, specific phases of the mission are remotely piloted while other phases are under autonomous control, thus blending the advantages of both man-in-the-loop and autonomous operations. For instance, mundane and time consuming tasks, such as aircraft station keeping and searching for enemy targets, are accomplished autonomously using the vehicle's onboard sensors and computer. Once a potential target is identified, human decision makers become involved to verify target identification and ensure acceptable conditions exist for weapon release. The advantages of this type of control system are that the most dynamic phase uses man-in-the-loop control, thus increasing the likelihood of success. Also, the standard rules of engagement model is maintained, minimizing the probability of misidentification and engagement of non-combatants. The disadvantages of this system are that communications links are still susceptible to jamming or interference and incorporating several people into the decision making process will substantially increase the time it takes to authorize weapons release and subsequently engage targets.

Looking Into the Crystal Ball: The Generation After Next

From the descriptions of naval UCAV on the drawing board, it is apparent that these vehicles will likely incorporate long range surveillance sensors, electronic surveillance equipment, and precision weapons. Since the Marines do not have a UCAV program underway, it appears doubtful that they will get a dedicated UCAV for their use in the near future; however, it might be possible to modify a land-based Predator for use with close-air-support and surveillance missions. A near-term plan is in place, but what will naval UCAVs look like 25 years from now?[21] By looking at the current research by DARPA and the services, we can hope to glean a look into the future.[22]

Minesweeping

While not specifically utilized on unmanned aircraft, DARPA has successfully used a chemical “sniffer” to detect buried landmines.[23] Using similar technology, a swarm of miniature UCAVs could fly over the amphibious landing area or known minefield to "sniff" out buried landmines. Once a landmine is detected, a single vehicle would lightly land next to the landmine. All of these vehicles would detect their own respective landmine, and once the swarm of UCAVs had detected the buried landmines, they would all detonate their onboard incendiary device in unison; thus, destroying themselves and the respective landmine. The signal to detonate their onboard explosive would come from personnel manning the UCAVs’ single control station, which would preclude unintentional detonation or collateral damage.

Smart Grenade

As indicated by the Marine's desired use of the Dragon Eye unmanned vehicles for reconnaissance and surveillance, small UCAVs will serve a tactical benefit in the field. Miniaturized variants of the Dragon Eye could be modified to carry a small incendiary device. Marines on the ground could remotely pilot this miniaturized aircraft while using its onboard sensors to look for enemy troops or ground vehicles. Once a target is detected and identified, the marine could pilot the aerial vehicle into the target, causing the miniature aircraft to detonate and destroy its target. In its simplest form, this miniature aerial vehicle would be used just like a grenade, except this grenade flies around corners and down passageways.

Air-to-Air

The Air Force is currently looking at putting an air-to-air version of Raytheon's *Stinger* missile, originally designed as a handheld ground-to-air missile, onto the Predator UAV.[24] UCAVs performing the air-to-air mission is a logical next step. While personnel aboard command and control aircraft can determine if the hostile identification and rules of engagement are being met using beyond visual range criteria, the air-to-air UCAV could easily engage enemy aircraft utilizing its own weapons system.[25] The U.S. 24-hour air patrols over New York City and Washington D.C., following the acts of terrorism of September 11, 2001, were stopped due to a reduced threat and expense of flying the missions. The Navy and Air Force flew over 19,000 combat air patrols over American cities at a cost of over $500 million.[26] If the need to reinstate these combat air patrols arises again in the future, air-to-air UCAVs could perform this mission at a substantial reduced operational cost and free up aircrew for other critical missions.

Amphibious Support

The Navy's current UCAV plan only discusses the use from aircraft carriers. However, future unmanned vehicles could be housed within the round of a naval artillery shell.[27] Once fired, the UCAV and shell would rapidly penetrate an enemy's defended beachhead, and then the vehicle would separate from the shell and begin powered flight. Imagery of the enemy's defenses would be sent back to the ship or Marine Expeditionary Unit. Once an enemy target is detected, the UCAV would be remotely piloted to detonate upon impacting the target. Such UCAVs necessitate a small, inexpensive, and ruggedized vehicle design to survive the accelerations of being fired from a naval gun.

Conclusion

With the advancement in technology and increased funding by Congress, naval variants of unmanned combat air vehicles will soon perform SEAD, strike, and ISR missions. Furthermore, UCAVs promise to perform some missions more effectively and less expensively than manned aircraft. A short-term outcome of using UCAVs could be a reduction in the number of Joint Strike Fighters bought by the services. According to John Pike, director of Globalsecurity.org, a non-partisan think tank in Washington D.C., "One could very easily imagine the JSF program getting substantially truncated because UCAVs turn out to be able to do everything JSF can do." Some have even predicted JSF will be the last manned strike aircraft built.[28]

Although UCAVs will tend to become more autonomous, it should be expected that a man-in-the-loop system will be utilized in the weapons engagement mission phase to preclude misidentification of the target, resulting in the death of civilians. UCAVs should not be used in

combat just because they can, but only if they provide a significant operational or tactical advantage over manned aircraft. Moreover, these unmanned vehicles should not be viewed as the antagonist to manned aircraft but should be considered as a tool for accomplishing the mission and defeating the enemy. While the future applications of UCAVs are as varied as a person's imagination, their use will help to keep the U.S. military the premier fighting force in the world.

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[1] Marc Strass, "Air Force Stands Up First Armed Predator UAV Squadron," *Defense Daily International*, Vol. 2, Issue 19, March 15, 2002.
[2] Thomas G. Mahnken, "Transforming the U.S. Armed Forces: Rhetoric or Reality?" *Naval War College Review*, Summer 2001.
[3] David A. Fulghum, "Directed Energy Weapons To Arm Unmanned Aircraft," *Aviation Week & Space Technology*, Vol. 156, No. 8, February 25, 2002: 28.
[4] Robert Wall and David Fulghum, "Navy UCAV, Other Designs Define Future Research," *Aviation Week & Space Technology*, November 20, 2000: 52.
[5] "DARPA and Navy Select Naval UCAV Contractors," *DefenseLINK*. www.defenselink.mil, posted June 30, 2000.
[6] There is a good reason why both the Navy and Air Force want their UCAVs to perform the suppression of enemy air defenses mission, and that is because the UCAV's inherent design makes it ideally suited for the mission. Since UCAVs can get closer to a target area to pick up low-power fire control radars without endangering aircrews, they provide a tactical advantage over manned aircraft. The UCAVs can penetrate deep into enemy territory, avoiding detection through their stealth design and small radar cross section, and once an enemy ground radar is detected, the unmanned vehicle can launch its anti-radiation missile. Since UCAVs promise extended endurance and on-station time, cycling several vehicles can provide continuous suppression of enemy air defenses.
[7] Robert Wall and David Fulghhum, "New Demonstrator Spurs Navy UCAV Development," *Aviation Week & Space Technology*, February 19, 2001.
[8] Frank Fernandez [Director of Defense Advanced Research Projects Agency], Statement before the Subcommittee on Emerging Threats and Capabilities, Committee on Armed Services, United States Senate, March 21, 2000: 20.
[9] Bruce Byrum, "U.S. Naval Forces and Unmanned Aerial Vehicles," *Naval Forces*, Vol. 22, Issue 2, 2001.
[10] Marc Strass, "Marine Corps Plans to Deploy Dragon Eye UAV to Protect Kabul Embassy," *Defense Daily International*, March 19, 2000. Each system consists of three UAVs and a ground station.
[11] Donald H. Rumsfeld, *Quadrennial Defense Review Report*, Washington, DC: Department of Defense, September 30, 2001: p IV.
[12] Greg Jaffe, "New and Improved?" Special Report: Spending For Defense, *Wall Street Journal*, March 28, 2002.
[13] Ibid.
[14] John A. Tirpak, "Send in the UCAVs," *Air Force Magazine*, August 2001: 58
[15] An order of magnitude change is the shifting, left or right, in place numbers (such as the 1's, 10's, or 100's) and is generally viewed as a change by a factor of 10. Notwithstanding, computer science or software programming professionals would have serious objections to this thought since it denotes bias toward the "base 10" numbering convention bias. These professionals may routinely use base 2, 8, or 16 numbering systems (also referred to as binary, octal, and hexadecimal numbering conventions). Even though the selection of any numbering system is somewhat arbitrary, a base system needs to be decided to quantify transformation. Taking the most conservative approach, an order of magnitude change in the base 2 system (a doubling or halving) will be used to quantify transformation.
[16] A technological challenge with operating naval UCAVs is the required communications and control system with the ground station or ship. Presently, a common Tactical Control System is envisioned for direct connectivity and interoperability with an entire family of future UAVs and UCAVs. The challenge with any future system, especially

shipboard ones that use a directive antenna, is not losing connectivity between the unmanned aircraft and ship while either is maneuvering significantly.

[17] Tirpak: 58.

[18] Marvin Leibstone, "More About the U.S. NMD, Pegasus and USN UCAV Programs," *Naval Forces*, Vol. 22, Issue 4, 2001: 9.

[19] Strass, "Air Force Stands Up First Armed Predator UAV Squadron."

[20] One possible application using a purely autonomous system is during "kill box" operations. In this type operation, it is acknowledged that no friendly or neutral persons are operating within a determined geographic area, and supposes that anyone within the "kill box" is the enemy. As long as the UCAV identifies targets within the predetermined area, this tactic eliminates the need to identify whether a target is enemy or not.

[21] Henry C. Barlett, G. Paul Holman, Jr. and Timothy E. Somes, "The Spectrum of Conflict: What Can It Do for Force Planners?" *Strategy and Force Planning,* 3rd Edition, (Newport, RI: Naval War College Press, 2000), 455. Using this example, the "military after next" timeframe begins in 2025.

[22] It is critical that UCAVs be used when they are the "right tool for the right job." In general, they should not be used in performing the mission for which cruise missiles have traditionally been used. Cruise missiles are characteristically employed against fixed land targets and fly a specific, predetermined flight path. Furthermore, cruise missiles are a one-time use weapon. Most UCAV proponents advocate a reusable vehicle that will takeoff, perform its mission, and land so to get it ready for the next sortie. As technology advances and the cost to produce UCAVs decreases, there may be temptation to use it in a throwaway capacity, such as to deliberately sacrifice it to destroy an enemy position. This tactic may be quite viable against mobile targets and when the UCAV has no weapons left to destroy the target.

[23] Fernandez: 39.

[24] David Fulghum and Robert Wall, "Stinger Eyed for UAV Role," *Aviation Week & Space Technology*, Vol. 156, Issue 9, March 04, 2002: 44.

[25] Because of the highly dynamic and ever fluid nature of "within visual range" air-to-air tactics, it remains to be seen if a UCAV's onboard sensors (electro-optic and radar) can maintain target track and lock while maneuvering under variable G's.

[26] Thom Shanker, "Officials Defend Plan to End 24-Hour Patrolling of Cities," *New York Times*, March 20, 2002.

[27] "US Forces Study Sensor-Equipped Munitions," Jane's International Defense Review, www.janes.com, posted September 01, 2001. Article describes Army and Marine Corps initiatives to develop a howitzer and naval gun munitions to conduct long range targeting and battle damage assessment.

[28] David Bowermaster, "Boeing's Pilotless Fighter Could Make JSF Obsolete," *The Seattle Times*, Fourth Edition, October 26, 2001.